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# THE PUERCO AND TORREJON FORMATIONS OF THE NACIMIENTO GROUP<sup>1</sup>

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## INTRODUCTION

The formations of the Nacimiento group are subjects of much interest to science because of the character of their vertebrate faunas and the positions they occupy in the time-scale of geologic history. The fossil mammals of the two formations have been carefully discussed by eminent paleontologists and yet but little is known of their areal distribution or stratigraphic occurrence. This paper is accompanied by the first contribution of detailed geologic mapping in the area of their type-localities, and is the result of research which has brought forward some important facts and thrown considerable light on the problem of their faunal and stratigraphic relationships.

The Nacimiento group was deposited during that long period of fresh-water conditions which prevailed over the greater part of western North America at the ending of the Cretaceous and the beginning of the Tertiary periods. In recent years paleontologists have considered the group as being earliest Tertiary in age, and thus marking the beginning of the Eocene series.

It is intended in the following pages to review the formations of this group, their correlations, etc., from the first discoveries to the present time and to set forth clearly the facts of their stratigraphic

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relationships in the light of new evidence; to present the first detailed geologic map of the upper Rio Puerco region; to discuss the physiographic changes which have taken place in that district between the close of the Cretaceous and the beginning of the Wasatch (Eocene); to present a list of fossil vertebrates with photographs of certain species apparently new to science; and to furnish a bibliography relating to the subjects under discussion.

#### HISTORY OF THE PUERCO

The Puerco formation was first described by Professor E. D. Cope in the *Annual Report of the Chief of Engineers to the Secretary of War* for the year 1875. His report deals with the geology of that part of northwestern New Mexico examined by him during the field season of 1874 when he discovered the Eocene deposits of what has since been called the San Juan Basin, from the river of that name which crosses it. This basin is in the extreme northwest corner of New Mexico and southwest corner of Colorado (see Fig. 1). On this map, the area inclosed by heavy black lines represents that examined by the writer in 1907 and is a miniature of the larger map presented herewith. The area described by Cope in connection with his Puerco formation is mainly along the east side of this district.

Inasmuch as the original description of Cope is of prime importance in the present discussion it is well here to quote his remarks on the Eocene Plateau or that portion of the San Juan Basin just west of the Sierra Nacimiento Mountains. In the following quotation, the names of formations referred to by Cope as correlated by the writer with those of the present time, are placed in brackets.

#### EOCENE PLATEAUS

West of the hog-back of Cretaceous No. 3 ["Laramie"] at an interval of perhaps two miles, at a point just north of the Gallinas Mountain, a sandstone bluff [Wasatch] presents a bold escarpment to the northeast. This is the angle of a mass of rock whose eastern face extends southward parallel to the mountain-axis, and whose strata dip first  $15^{\circ}$  and then  $10^{\circ}$  south, and soon disappear beneath a similar mass. This series [Wasatch] also presents an escarpment to the northeast, and its beds also dip  $10^{\circ}$  south, nearly opposite the cañon of the Gallinas. This façade rises to from 600 to 900 feet elevation, and is cleft to the base by a deep gorge, the Cañoncita de las Vegas. I traversed this fissure, passing entirely through to the elevated country to the westward. Six miles from its mouth is a large pool, fed by a spring known as the Mare's Spring. The cañon is narrow,

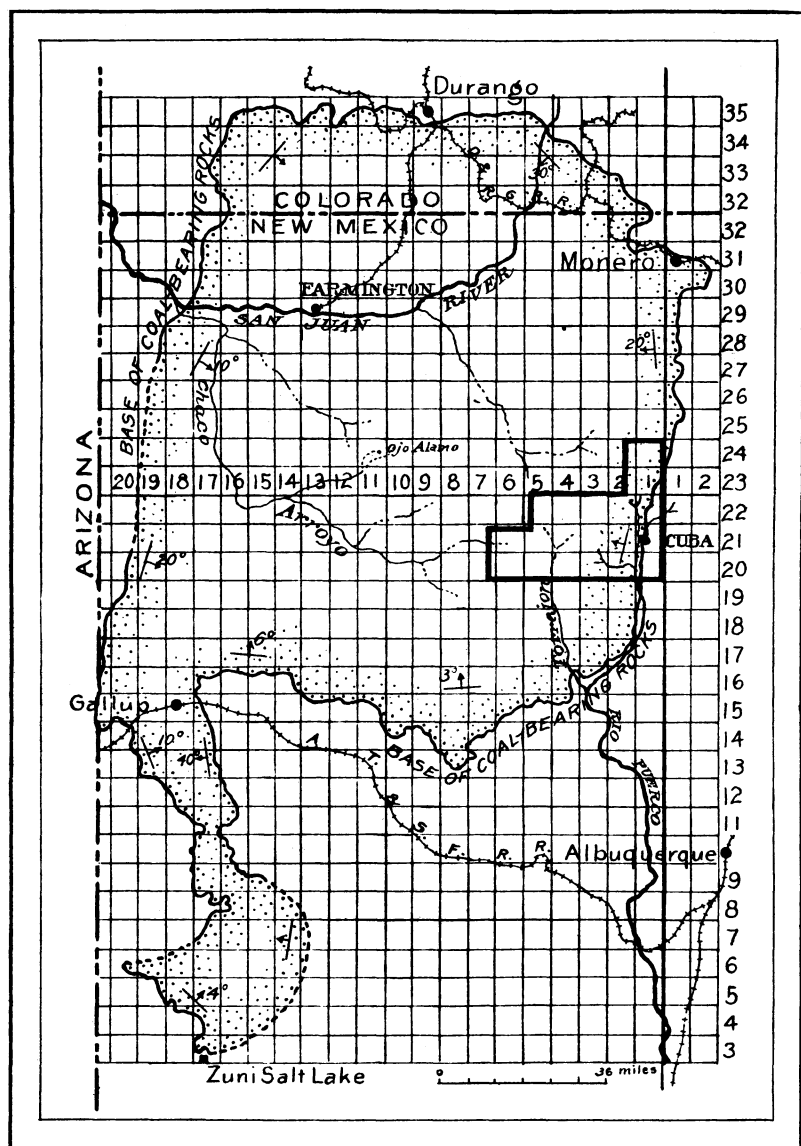


FIG. 1.—Sketch map showing relation of the Puerco-Torrejon locality to the San Juan Basin.

and the walls almost perpendicular. They are composed at the "puerta," or entrance, of a moderately hard, reddish-brown sandstone. The cañon is twenty miles in length, its bottom has a gentle rise; and as the sandstone has a gentle dip toward the west as well as south, its upper beds reach the level of the bottom at about the middle of the length of the cañon. Above them softer beds [Wasatch] appear, alternating with strata of sandstone; the beds are first gray, but others soon appear which are striped with red. The red-striped marls increase in relative thickness toward the west, and the sandstone strata diminish until at the head of the cañon the high lands fall off in masses of hills of bright-colored marls eroded into rounded and picturesquely formed hills. These extend in a long line to the north and the south, facing westward. To the west, a wide, elevated plain spread before us, varied with a few hills, and stretching away with a gentle slope to Cañon Largo and the country of the San Juan River. The discovery of the variegated marls was one of no little interest to the writer, inasmuch as I had made special efforts to find Eocene beds in this region, and they were now crowned with success. The position of these marls, with their close physical resemblance to the Wasatch beds of Bear River, Wyoming, together with the evidence furnished by a lower molar of *Bathmodon*, discovered by my guide, indicated that I had discovered the sediments of the great body of fresh water which during successive stages of the Eocene period occupied the drainage-basin of the Great Western Colorado. The thickness of the strata exhibited in the walls of the Cañoncita de las Vegas, I estimated at 1,200 feet.

On leaving the mouth of this cañon, and proceeding southward, the southern dip of the red sandstones [Wasatch] brings their summit to the ground-level in about ten miles' distance. The red and gray marls with alternating beds of white and yellowish sandstone [Wasatch] appear on their summits, and at a point twenty miles south of the cañon, form a mass of badland bluffs of from 600 to 1,000 feet elevation. This escarpment retreats and then turns to the east, forming an extensive horseshoe, the circumscribed area being occupied with hills and picturesque masses of sediment, with all the peculiar forms and desolation of badland scenery. I remained in camp for about a month near this circle, and obtained many fossil remains of vertebrates [Wasatch]. Ten miles south of this point another horseshoe of badlands covers an extensive area, and proved to be as rich in fossil remains [Wasatch] as the first. Here I made my second camp, remaining in it for three weeks. The southern boundary of the northern tract extends to within six miles of the Cretaceous hog-backs, while the corresponding part of the second approaches nearer, forming a line of bluffs of considerable height running north and south parallel with, and half a mile from, the hog-backs. Beyond the Puerco divide, hills of this formation rise on both sides of the trail, and near the Ojo de San José, the Eocene beds repose on the foot of the Nacimiento Mountains several miles to the east.

Below the sandstones which form the portals of the Cañoncita de las Vegas, another stratum of marls [Puerco] shows itself in hills of 100 feet and higher, in the sage-brush plain that separates them from the Cretaceous hog-backs. They

are soft and of mixed black and dark-green colors near the locality in question, and capped by light and yellowish sandstones. These are the lowest beds of the Eocene, and I traced them for forty miles to the south along the belt of country intervening between Cretaceous No. 4 ["Laramie"] and the reddish sandstone [Wasatch]. At the locality just mentioned they conform to the sandstones above, having a dip of  $10^{\circ}$  southwest, while they do not conform to the hog-back of Cretaceous No. 4 ["Laramie"], the nearest available outcrop, which dips at  $25^{\circ}$  west. Farther south this marl is represented by low hills of generally lighter color. Near Nacimiento it has an increased importance, as it rises both to the east and south. The valley of the Upper Puerco is excavated in it for some distance, and its blackish, greenish, and gray hills are seen on both sides of the river. At a point on the river about six miles below the village of Nacimiento, the lower sandstone of the Eocene forms a perpendicular bluff, which terminates in an escarpment of 500 feet elevation facing the south. The red-striped marls [Wasatch], having acquired a gentle northern dip, disappear from view some miles to the north, and the termination of the underlying sandstones warned us that we were approaching the southern border of the basin.

The border of the sandstone turned to the west at this point, the line of bluffs continuing as far as vision extended. Below and south of it, the varied green and gray marls formed the material of the country, forming badland tracts of considerable extent and utter barrenness. They formed conical hills and flat meadows, intersected by deep arroyos, whose perpendicular walls constituted a great impediment to our progress. During the days of my examination of the region, heavy showers of rain fell, filling the arroyos with rushing torrents, and presenting a peculiar character of this marl when wet. It became slippery, resembling soap in consistence, so that the hills were climbed with great difficulty, and on the levels the horses' feet sank at every step. The material is so easily transported that the drainage-channels are cut to a great depth, and the Puerco River becomes the receptacle of great quantities of slimy-looking mud. Its unctuous appearance resembles strongly soft-soap, hence the name Puerco, muddy. These soft marls cover a belt of some miles in width, and continue at the foot of another line of sandstone bluffs, which bound the immediate valley of the Puerco to a point eighteen miles below Nacimiento. Here the sandstone again turns to the westward presenting a southern escarpment of 500 to 1,000 feet elevation. I could not be sure whether this sandstone is identical with that of the escarpment twelve miles north, but suspected it to be such. [It is a lower sandstone and is Mesaverde.] Immediately south of it, low hills of Cretaceous No. 4 (?) [Mancos] extend across the Puerco [River] and continue south of the Eocene (?) bluffs at a distance of a mile or two with a western strike. They were as elsewhere of a soft yellowish sand and clay, including shale beds, and contained abundance of *Inoceramus*, like those found on the Gallinas.

Ten miles to the southward, the underlying Cretaceous beds are capped by a horizontal table of basalt (Mount Taylor flow) thus forming a mesa, through which the Puerco passed in a cañon. I supposed this to be the forerunner of

the great basaltic plateau which, according to Lieutenant Wheeler, constitutes the country south of the Rio Chaco for a great distance, one of little promise to the agriculturist. The season being well advanced, October 22, I thought best to commence the return march, which we accordingly did.

The soapy marls, or, as they may be called, the Puerco marls, have their principal development at this locality. I examined them throughout the forty miles of outcrop which I observed for fossil remains, but succeeded in finding nothing but petrified wood. This is abundant in the region of the Gallinas, and includes silicified fragments of dicotyledonous and palm trees. On the Puerco, portions of trunks and limbs are strewn on the hills and ravines; in some localities the mass of fragments indicating the place where a tree had broken up. At one point east of the river I found the stump of a dicotyledonous tree which measured five feet in diameter.

As already remarked, the Puerco marls belong to the Eocene series in their strict conformability to the superincumbent rocks of that age. They do not appear to represent the Fort Union or Lignite beds of northern Colorado and the North, as they differ in almost every respect. They contain no lignite nor coal, although their occasional black color may be due to a small amount of carbonaceous matter. They have no resemblance to the Fort Union beds in mineral character or fossils. I conclude, as a result of the investigation, that the latter formation has no existence in this part of New Mexico. The presence of such quantities of petrified wood gives weight to the probability that the Puerco marls are a lacustrine formation.

The geography of the greater part of the district referred to in the above quotation is shown on the topographic geologic map presented herewith. This map does not extend far enough northward by about seven miles to include the Canyoncita de las Vegas mentioned by Cope; however, that drainageway was identified in the geologic study of the general district and is now shown on the new topographic sheet of the Gallina quadrangle by the U.S. Geological Survey.

As shown on the map, about five miles west of north of Gallina the base of the Wasatch formation swings away from the Cretaceous hog-backs forming the south boundary of the "extensive horseshoe" referred to in the quotation from Cope where he obtained many fossil remains of vertebrates. He mentions another horseshoe ten miles south of this also rich in fossil vertebrates; the southern area is about four miles north of what is now known as La Jara P.O. However, the horseshoe here is not formed by the extreme base of the Wasatch as is the case farther north. In the La Jara district the present writer obtained numerous vertebrate teeth and skeletal remains.

In the last paragraph of the above quotation of Cope's description, he states that the "Puerco marls" do not appear to represent the Fort Union or "Lignite beds of the North"; in writing later on the subject for the Geographical Survey west of the One Hundredth Meridian (*Annual Report* [1877], Part II, p. 18) he remarks that these beds "may represent the Fort Union or Lignite beds of the Upper Missouri some of whose strata they resemble in color and consistence." These remarks are noted with interest since recent explorations have shown that Torrejon fossils, which characterize the upper part of Cope's original Puerco, do occur in the Fort Union beds of Montana.<sup>52, 68</sup> Cope states that he did not succeed in obtaining fossil remains from the Puerco, other than petrified wood, and mentions finding numerous fragments of silicified limbs and trunks of dicotyledonous and palm trees, among them one stump which measured five feet in diameter. (See Fig. 7, this paper.) These remains are indeed abundant in this vicinity; on the summit of the mesa two miles west of Cuba post-office, which is the village Nacimiento, there are some ancient stone ruins which were built in large part of specimens of silicified wood.

Although Cope was unable to find satisfactory fossils in the Puerco at the time of its discovery in 1874, he obtained in 1880 the services of an experienced collector, David Baldwin, of Farmington, New Mexico, to make careful search for vertebrate remains in that formation. Baldwin collected with great success at intervals for several years, evidently finding the first Puerco fossils in the vicinity of Nacimiento and northward where the formation was known to Cope. More than ninety species of fossil mammals were sent from the Puerco which were described by Cope between 1881 and 1888 in numerous papers presented to the American Philosophical Society, Philadelphia Academy of Science, and the *American Naturalist*. These papers were devoted exclusively to descriptions of the fossils, with the exception of a brief note on "The Relation of the Puerco and Laramie Deposits" in the *American Geologist* for October, 1885, here quoted from as follows:

Some writers having suspected the identity of the formations above named, and the consequence which follows, that the Puerco mammalian fauna was contemporary with the dinosaurian fauna of the Laramie age, the following observations on their stratigraphic relations are now given. They are derived from the



notes of several years' residence and exploration by my correspondent, David Baldwin, which connect those made by myself in New Mexico in 1874, published in the Wheeler Survey report, with those made by Holmes and Endlich in 1878 in Colorado, and published in the Hayden Survey report.

At the locality where best developed, the Puerco beds have a thickness of about 850 feet, and contain Mammalia to the base (see *Naturalist* for April and May, 1885). The Laramie beds succeed downward, conformably it is thought by Mr. Baldwin, and have a thickness of 2,000 feet at Animas City, New Mexico. They rest on Fox Hills marine Cretaceous of less thickness. A few fossils sent from time to time by Mr. Baldwin identify the Laramie. This is especially done by the teeth of the dinosaurian genus *Dysganus* Cope, which is restricted to the Laramie formation everywhere. Also by the presence of the genera *Laelaps* and *Didonius*, which in like manner do not extend upward into the Puerco beds. . . .

It is thus evident that the Puerco formation is quite distinct from the Laramie, although it is possible that it may be proper to associate it with the Laramie in the post-Cretaceous series. When the Cretaceous mammalian fauna comes to be known, it will be very apt to agree with the Puerco in its leading features. These are the absence of Perissodactyla and of Rodentia, and of course of mammalian orders not found below the Miocenes; and in the constitution of the mammalian fauna by Condylarthra, Bunotheria and Marsupialia exclusively. The post-Cretaceous series as a whole may be ultimately distinguished from the Tertiary by these peculiarities, together with the presence of the reptilian genus *Champsosaurus*.<sup>21</sup>

Concerning the taxonomy of the original Puerco, Cope was at first inclined to place the beds in the Eocene because of their apparent conformability at the top with beds known to be of that age. He freely referred to the "Puerco Eocene" in his earlier papers but in 1885 receded from this opinion and, on the basis of the Mesozoic affinities of the fauna, placed the Puerco in what C. A. White had proposed to call the post-Cretaceous. This term has been used more or less to the present time as signifying a zone between the known Mesozoic and Cenozoic eras. But it is evident that Cope considered the Puerco fauna more closely related to the Cretaceous than to the Tertiary faunas as indicated in the following quotation from the *American Naturalist*:

The fauna of this horizon is well distinguished from that of the Laramie in the absence of the numerous Dinosauria of the latter, and the presence of numerous Placental Mammalia in the former. On these grounds I at first referred the formation to the Cenozoic series, but further reflection induced me to place it as now arranged. The reason is as follows: Although Placental Mammalia are not now known otherwise from Mesozoic beds, the other forms of the Puerco are especially Mesozoic in character. Such are the Choristodere Reptilia and

the Multituberculate Marsupialia, neither of which occur above, while both occur below the Puerco, the Multituberculata down to the Trias inclusive. Then the Placentalia are entirely peculiar in the absence of the Diplarthra and of the Rodentia, orders always found in the Cenozoic beds. Then the characters of the Condylarthra and Amblypoda and many of the Creodonta, which represent Tertiary types, are so peculiar that we are led to suspect that when the Cretacic Mammalia are fully known they cannot differ very widely from those of the Puerco.

But one area of this formation is definitely known; that is in Northwestern New Mexico and Southwestern Colorado. It consists of sandstones and soapy marls, and has a thickness of 850 feet. It is immediately overlaid by the Wasatch Eocene, and rests on the Laramie.<sup>26</sup>

In the writings of various paleontologists since the time of Cope, the Puerco has been placed provisionally in the lowermost Eocene, as will be referred to in further paragraphs.

The statement has been made in geologic literature from time to time that the Puerco formation occurs in northwest New Mexico and southwest Colorado; but no beds known to be Puerco in age have yet been found in Colorado. This mistake arose from the work of Endlich in the San Juan region in 1875.<sup>7</sup> This was the year after Cope had discovered the formation at the head of the Puerco River in New Mexico to which he gave the name Puerco, and an attempt was made to correlate the beds on the opposite side of the San Juan Basin in New Mexico and Colorado. Holmes was working the same year along the La Plata and San Juan valleys west of Endlich. Both of these geologists described certain strata in their respective districts as "The Puerco Marls," basing the correlations entirely on lithologic similarity and stratigraphic position. It may be said in this connection that the term "marl," applied by Cope and others to these soft argillaceous and siliceous beds, was improper, since the term, though used loosely in the present day, necessarily implies strongly calcareous material.

At the time of the work of Endlich and Holmes and until the work of the writer in 1907,<sup>70</sup> it was not known that the Nacimiento group lies unconformably on the "Laramie" and is in turn overlain unconformably by younger formations. For this reason, it was naturally assumed by the geologists of that time that beds in the same basin lying next above the "Laramie" were Puerco in age. But the formation described by Endlich in Colorado<sup>7</sup> as Puerco is the Animas

formation described and named by Cross in 1892.<sup>34</sup> It is probable that the Puerco of Endlich included some of the lower members of the Wasatch which was determined in 1909 by J. W. Gidley and the writer to lie next above the Animas formation in this portion of the basin. The beds described by Holmes<sup>8</sup> as Puerco in his Pinyon Mesa section, about six miles north of the San Juan River and just west of the La Plata River in New Mexico, may be either Puerco or younger in age. He characterizes the formation as consisting of "soft sand, clays, and marls, highly colored with reds, yellows, and purples, growing gray below and containing masses of soft sandstone." This description agrees more closely with the Canyon Largo series of Newberry<sup>1</sup> than with the Puerco. Holmes correlates Newberry's Canyon Largo series with the Wasatch, which is probably correct, since the beds occupy the innermost portion of the San Juan Basin and could not well be older than Wasatch even though Newberry referred the whole series to the Cretaceous.

Besides the collections of David Baldwin made during the years 1881 to 1888 no contributions were made to the Puerco fauna until the year 1892. Baldwin died at his home in Farmington, New Mexico, several years ago, and thus was lost to science a valuable collector and with him much information never placed on record relative to the geographic locations of many fossil-bearing districts. His original collections which were described in numerous papers by Cope were purchased in 1895 by the American Museum of Natural History in New York City.

In 1892 and 1896 the American Museum of Natural History sent expeditions into the San Juan Basin for the purpose of further study of problems connected with the Puerco fauna. This work was under the direction of Dr. J. L. Wortman. As a result of these expeditions, a large amount of new material was obtained.

Some time after the first season's collecting by Wortman in 1892 a paper was written by Professor H. F. Osborn and Mr. Charles Earle entitled "Fossil Mammals of the Puerco Beds."<sup>37</sup> In this paper they quote the following field notes from Wortman:

The thickness of the beds is roughly estimated at 800 to 1,000 feet, and as far as can be observed they lie conformably upon the Laramie. At no place examined by us can fossils be said to be abundant, but on the contrary most of the exposures are entirely barren. For convenience they are divided into Upper

and Lower Beds, but this scarcely gives an adequate idea of the occurrence of the fossils, for the reason that it is only the extreme upper and lower strata that are productive; the great intermediate part we found to be singularly barren.

The lower fossil-bearing strata occur in two layers, the lowermost of which lies with ten or fifteen feet of the base of the formation. This is succeeded after an interval of about thirty feet by a second stratum in which fossils are found, and this appeared to be by far the richer of the two. Both of these strata are of red clay, and at no place did we find them more than a few feet in thickness.

The lower horizon we found exposed in two places, viz.: the head of the Coal Creek or Pina Verta Cañon, and some of the upper tributaries of the Chaco Cañon. It is especially and sharply distinguished by the occurrence of the remains of *Polymastodon*, which appear to be entirely absent from the upper horizon.

Fossils are much more abundant in the upper strata, and wherever a good exposure was found their occurrence could be more confidently looked for. The genera *Chirox* and *Pantolambda* appear to belong exclusively to the upper beds. Owing to the widely separated localities and the general scarcity of fossils, it is at present impossible to say whether it is one or several layers that produce the fossils from these upper beds. It is my opinion, however, that there are several layers, and that their vertical range is somewhat greater than that of the lower horizon. The principal localities of the upper strata are as follows: head of Cañon Gallego, Cañon Blanco, Cañon Escavada, and head of Cañon Chaco.

It will be noted that near the beginning of the above quotation Wortman states that the Puerco beds "as far as can be observed lie conformably upon the Laramie." This statement is somewhat qualified perhaps, due to the uncertainty which necessarily arises from a study of formation contacts in undisturbed, unconsolidated deposits; it is especially difficult to recognize an unconformity in badland topography in the absence of abundant fossils and especially so without detailed, continuous mapping.

Wortman states that the two lower fossil zones lying within fifty feet of the base of the Puerco are characterized by the remains of *Polymastodon*, whereas the fossil zone near the top contains *Chirox* and *Pantolambda* which do not occur in the lower beds. In fact the faunas of the upper and lower beds of the original Puerco were found to be entirely distinct, which later led to the substitution of the name Torrejon formation for the upper strata and the restriction of the name Puerco formation to the lower beds.

## HISTORY OF THE TORREJON

The possibility of distinction between the faunas of the upper and lower beds of the original Puerco had been noted by Cope. In his paper on the "Synopsis of the Vertebrate Fauna of the Puerco Series"<sup>29</sup> in 1888 he stated that the information at that time available indicated some faunal difference between the lower and upper beds. In bearing out this view he gave a list of twenty species peculiar to the lower beds, leaving to research to determine whether or not they occur also in the upper beds.

After the field expeditions of the American Museum of Natural History in 1892 and 1896, a systematic revision of the fauna from Cope's Puerco was taken up by Dr. W. D. Matthew, of that organization. In his paper of 1897 entitled "A Revision of the Puerco Fauna"<sup>44</sup> he emphasized the absolute distinctness in the faunas of the upper and lower beds, stating that they contain not a single species in common and that not a genus passes through without serious modifications of at least subgeneric value. The faunas were found to be as different as any other two successive Eocene formations, and it became necessary to adopt a new name to designate one of the two. It was then that Dr. Wortman proposed the name Torrejon formation for the upper beds, retaining the name Puerco for the lower. The name Torrejon was taken from the arroyo of that name in the type-locality. It has since been freely used and is firmly fixed in literature.

In 1901 Mr. Earl Douglass discovered Torrejon fossil vertebrates in Montana,<sup>52</sup> a fuller reference to which will be given under the head of "Correlations." With the exception of the one locality in Montana, no fossils have been found elsewhere in the United States corresponding to either of these unique faunas of the Nacimiento group of the San Juan Basin in New Mexico.

## NAMING OF THE NACIMIENTO

In view of the fact that the Puerco was restricted to the lower formation when the name Torrejon was proposed, and since it is very necessary to adopt a group name in order to properly discuss the relationship of the two formations, the writer proposes the name Nacimiento group for the two formations used collectively. The rela-

tion of the group to the two formations here discussed is shown as follows:

Nacimiento group { Torrejon formation  
Unconformity (?)  
Puerco formation

This name is taken from the town by that name in the type-locality at the foot of the Nacimiento Mountains. Here Cope mentions the importance of the "Puerco," which he used to include everything between the "Laramie" and the Wasatch in this region.

#### GEOLOGY OF THE TYPE-LOCALITY

The following observations and conclusions, together with the map, are based on the writer's field work in the summer of 1907 under the supervision of Mr. M. R. Campbell. In the preparation of the map and securing of geologic notes, valuable assistance was received from Mr. William J. Reed (deceased) and Mr. Albert L. Beekly.

The results of this work were chiefly of value in that a map was prepared of the region westward from the Sierra Nacimiento and on this the geology was imposed. The unconformable relationship of the Nacimiento group was noted for the first time and something was learned of the physiographic record of the district in the late Cretaceous and early Tertiary. Unfortunately, the advantage was not at hand of having paleontologic determinations in the field in order to know what formations were being dealt with at that time. For instance, no distinction could be made in the lithologic character of the upper and lower beds of the Nacimiento group, the result being that the Puerco and Torrejon formations were not mapped separately. At the time of the field work, the writer had not had occasion to be familiar with the literature on the Puerco, Torrejon, and Wasatch of this field, and did not know the stratigraphic position at which fossil vertebrates had previously been found. The results in paleontologic collecting were, however, all that could be expected under the circumstances and were sufficient to make possible definite correlations.

The region under discussion is one of little culture and sparse population. Gallina is a small Mexican settlement of about 100 people, located at the point where Gallina River emerges from the Sierra Nacimiento. About 14½ miles south-southwest is the old

Mexican town of Nacimiento, known to the postal officials as Cuba. This village contains about 200 inhabitants, and is located in a small fertile valley at the foot of San Pedro Mountain, near the point where Nacimiento Creek joins Rio Puerco. La Jara, Copper City, and Señorito are settlements of less importance. About thirty-four miles south of west from Cuba is Raton Spring, where there are two Mexican stores and a few dwelling-houses. Raton Spring is known also as Pueblo Pintado, a name formerly applied to the Aztec ruins, which are still evident at this place. The spring itself is a deep pool of some-



FIG. 2.—Puerco formation, ten miles west of south of Nacimiento, New Mexico

what alkaline water, which flows as a mere seep. At Ensina Spring, between Cuba and Raton, eleven miles north of east from Raton there are some Indian stone huts, but the spring is known as a watering-place for miles over the surrounding desert country. The water issues from beneath a massive sandstone, and the flow in August, 1907, was about one gallon per minute. These are the only localities worthy of individual mention here, but there are numerous Mexican ranches along the west foot of the Sierra Nacimiento between Gallina and Cuba.

On the west the Sierra Nacimiento presents a bold front, and along its slopes the sedimentary rocks are steeply inclined and

form hog-backs. At some places the slopes are extensively covered by boulders and wash, principally granite and granite porphyry from the mountain mass. The broad plateau country, stretching westward to San Juan River, is a dry, barren expanse of highly colored mesas and badlands, known as the Nacimiento Desert.

The following generalized section presents the stratigraphic

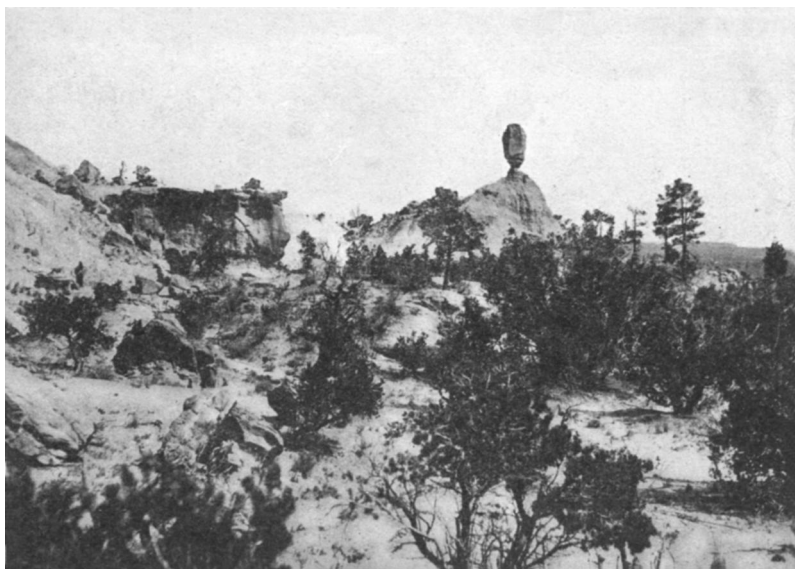


FIG. 3.—Silicified stump in Puerco formation, near Encina Spring, New Mexico  
relationship of the Nacimiento group in the region of the Puerco River:

GENERALIZED SECTION OF ROCKS IN THE PUERCO REGION

System	Series	Group or Formation	Thickness in Feet
Quaternary	Pleistocene	Recent terraces, etc. . . . .	0-50
Tertiary	Eocene	{ Wasatch formation (Unconformity) . . . .	1,000
		{ Nacimiento group (Unconformity) { Torreon formation (Unconformity?)	275
		{ Puerco formation..	560
Cretaceous	Upper Cretaceous	{ "Laramie" formation . . . . .	900
		{ Lewis shale . . . . .	500
		{ Mesaverde formation . . . . .	400
		{ Mancos shale . . . . .	1,000
		{ Dakota sandstone . . . . .	300



The character of individual strata composing the two formations of the Nacimiento group may be gathered from the following section along the west side of the Puerco River below Nacimiento:

SECTION OF NACIMIENTO GROUP ALONG PUERCO RIVER  
SOUTH AND WEST OF NACIMIENTO

(Wasatch formation)		Thickness
(Unconformity)		in Feet
Torrejon	Shale, variegated.....	20
	Sandstone, brown.....	3
	Shale, gray.....	15
	Sandstone, gray.....	3
	Shale, gray and soft sandstone.....	40
	Sandstone, massive, tan-colored.....	15
	Shale, yellowish.....	15
	Sandstone, massive, soft, coarse, tan-colored.....	120
	Shale, gray.....	20
	Sandstone, massive, soft, tan-colored.....	30
(Unconformity)		
Thickness of Torrejon formation		276
Puerco	Shale and soft sandstone.....	30
	Shale, dark, carbonaceous.....	10
	Shale, gray.....	10
	Sandstone, massive, yellowish, lenticular.....	10
	Shale, variegated.....	25
	Shale, dark carbonaceous.....	4
	Shale, chiefly yellowish.....	80
	Sandstone, massive, brown, lenticular.....	10
	Shale, variegated and soft, gray sandstone.....	200
	Sandstone, massive, coarse-grained, brown.....	40
	Shale, gray and soft sandstone.....	45
	Shale, very dark, local coal streaks.....	4
	Shale and soft sandstone of gray and tan colors.....	90
(Unconformity)		
Thickness of Puerco formation		558
(Lewis shale)		
Thickness of Nacimiento group		834

The section given above may be taken as typical for the beds of the Nacimiento group in the type-locality. The total thickness of either the Puerco or Torrejon is variable owing to the unconformities that limit each of these formations at the top. This limitation in thickness is brought about by erosion and removal of rocks during the time-interval after the close of each formation.

The Puerco and Torrejon formations are not sufficiently contrasted lithologically to permit of their being readily separated at all points without fossil evidence. Along the Puerco River, where erosion has removed the greatest amount of material the stratigraphic succession is more clearly exposed than at any other point within the area. Here the entire group, with a total thickness of about 835 feet, forms prominent escarpments, mesas, and badlands along a wide belt between the outcrops of the "Laramie" and the Wasatch.

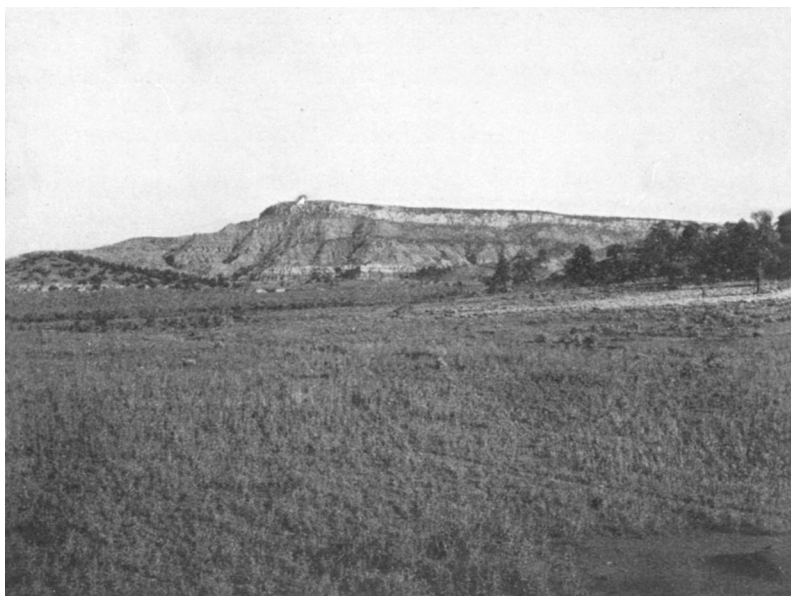


FIG. 4.—Torrejon formation, eight miles northeast of Encina Spring, New Mexico, showing one of the natural monuments from which the Arroyo Torrejon takes its name.

In this vicinity, the Puerco formation is characterized to some degree by the presence of dark to black layers of carbonaceous shale. At a point about three miles north of east of Nacimiento and at about the same horizon, near the base of the formation eleven miles west of south of the same town, there are local thin lenses of coal in the Puerco formation. In the Torrejon formation northeast of Encina Spring, where fossil mammals were found, thus enabling positive identification of those beds, there are occasional, lenticular layers of dark

carbonaceous shale very similar to the dark layers in the underlying Puerco; but on the Puerco River the carbonaceous layers are confined to the Puerco formation almost entirely.

Both the formations of the Nacimiento group consist essentially of variegated clay shale, arenaceous shale, and soft, coarse-grained sandstone of white, gray, and tan colors. Such beds are of that consistency necessary to the development of badland topography, with the exception of local, siliceous sandstones hard enough to form mesas or dip slopes through which intermittent streams cut canyons into the underlying shale. The latter is more particularly the type of topography in the vicinity of Nacimiento. The softer sandstones which commonly alternate with the arenaceous and clay shale usually weather to soft incoherent sand at the outcrop. These beds have been said to consist in part of unconsolidated sand but the writer has found the term applicable only to weathered exposures; for in every case the sand is solid at a short distance from the surface.

There are local conglomerate layers in both the Puerco and Torrejon but they are of minor importance and exceptional. No one member of either of the formations is a true conglomerate such as the basal conglomerate of the Wasatch formation. However, occasional lenses of small quartz and chert pebbles are to be seen in the more massive, coarse-grained, siliceous sandstones.

The basal sandstone of the Wasatch is strongly conglomeratic, consisting of pebbles averaging the size of an egg and of varied composition; the pebbles consist of quartz and chert, of red, black, brown, and white colors, and various crystalline rocks. The matrix is composed chiefly of coarse, brown quartz grains. This sandstone is a prominent horizon-marker over a wide area on the south and east sides of the San Juan Basin. On the north side of the basin, in southwest Colorado, where the Wasatch rests on the Animas formation, this conglomerate member is absent.

With the exception of the conglomerate above mentioned the formations of the Nacimiento group are lithologically distinguished only in a slight degree from the overlying Wasatch. The Wasatch contains a larger percentage of highly colored shales and softer sandstones than the Nacimiento, but otherwise the composition is not materially different. The contrast of the Nacimiento group with the "Laramie"

of this basin is more marked since the latter consists largely of massive brown sandstones alternating with drab, clay, and arenaceous shale together with local carbonaceous shale and coal beds.

The structure in the area under discussion, with the exception of unconformable relationships in strata, is such as is common around the margins of most of the minor basins in the Rocky Mountain province. Steeply inclined strata limit the older sedimentary rocks along the boundary of the Nacimiento Mountains, the dips decreasing westward toward the interior of the San Juan Basin. (See



FIG. 5.—Upper escarpment of Nacimiento group, four miles southwest of Nacimiento, New Mexico.

sketch map, Fig. 1.) Near the mountains, this inclination varies from  $35^{\circ}$  north of Gallina to more than  $90^{\circ}$  at Copper City and northward. In the latter district, the fold is overturned and dips  $70^{\circ}$  eastward toward the mountains. All the sedimentary formations above the Jurassic have this inclination with the exception of the Wasatch. About ten miles northwest of Gallina the Wasatch has an inclination of about  $10^{\circ}$  west of south as mentioned by Cope<sup>5</sup> and verified by the writer. The dip in that vicinity is apparently local and is of more recent date than any uplift in the Nacimiento Mountains as shown by the fact that the Wasatch beds rest nearly horizontally against the crystalline rocks of those mountains between Gallina and Nacimiento.

Along the Arroyo Torrejon, the Cretaceous and Tertiary formations are very slightly disturbed; the dips in this region are probably initial slopes with the exception of local variations produced by settling of the strata; the latter are noticeable in the Torrejon beds on the east fork of the Arroyo Torrejon near the Escavada road.

The Nacimiento group is limited by very evident unconformities at the top and bottom as shown on the accompanying map. The more evident of these two unconformities is the one at the top, or at the base of the Wasatch formation. Between Gallina and Nacimiento the Wasatch covers the outcrops of sedimentary rocks, including the Nacimiento, "Laramie," Lewis, Mesaverde, Mancos, Dakota, and older formations. Four miles northeast of Nacimiento, where the Wasatch covers the upturned edges of older rocks, and from there northward along the foot of the mountains, the unconformable relationships are strikingly shown. This overlap of the Wasatch on older beds is equally evident four miles northwest of Gallina, where the soft, variegated shales swing across nearly to the Mesaverde hog-back. This unconformity at the base of the Wasatch is not easily recognized away from the mountains. The contact with the underlying formation of the Nacimiento group on the Arroyo Torrejon would not ordinarily be considered unconformable; for there is no discordance in dip in that section and there is no contrast in either composition or color of the sediments on either side of the contact. The variegated shale and soft sandstone of the Torrejon and Wasatch on respective sides of the unconformity are very similar. These facts, together with the variability in color and lenticular character of deposits in each of the formations, make this unconformity very difficult of detection except where the stratigraphic break is recorded in the dynamic structure. The same holds true for the unconformity at the base of the Puerco.

The unconformity at the base of the Puerco formation is evident at the point eleven miles southwest of Nacimiento, where the "Laramie" sandstone, shale, and accompanying coal beds appear from beneath the Puerco striking nearly at right angles with it. Westward from this locality, where the outcrops are nearly parallel and there is no inconsistency in direction of dip, the unconformity is not so easily noted.

The hiatus between the "Laramie" and the Puerco apparently does not represent so great a time-interval as that between the Torrejon and the Wasatch. The indications are that the unconformity at the base of the Puerco is in part one of overlap. The angularity is slight between it and the underlying "Laramie" and Lewis shale. However, the direction of strike at the point of overlap is not the same as in the lower formation, which fact probably indicates a slight folding of the Cretaceous rocks and subsequent erosion previous to the deposition of the Puerco formation. On the other hand, the

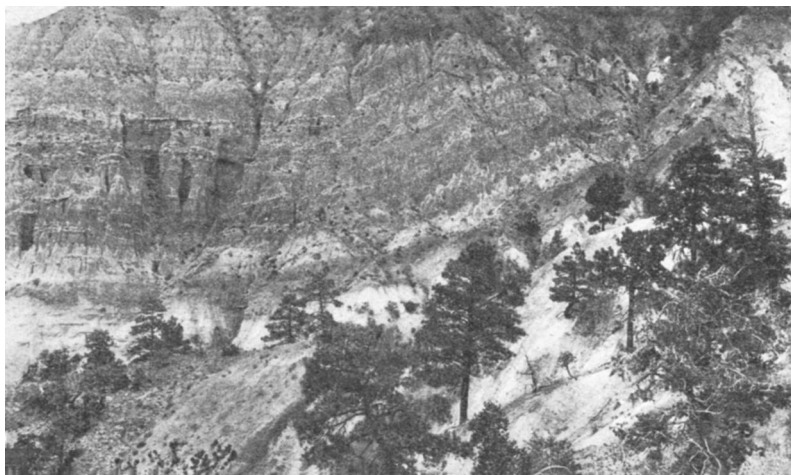


FIG. 6.—Shale of the Nacimiento group, three miles northeast of Nacimiento, New Mexico. Tilted to vertical by uplift of the Nacimiento Mountains.

break at the base of the Wasatch is represented by a very strong angular unconformity indicating a long period of erosion previous to its deposition, after the close of the Torrejon.

The unconformity between the Puerco and Torrejon formations cannot be noted in the field except on fossil evidence. It is highly probable that it is one essentially of overlap with very little stratigraphic break. The two formations are so closely similar in lithologic character that it is difficult to distinguish one from the other without the assistance of fossils. For this reason, the two could not be indicated separately in the brief season spent in the preparation of data for the accompanying map. However, the base of the Torrejon is

known at certain points and the inconstant thickness of the interval between this horizon and the base of the Puerco indicates the unconformable relationships between the two formations. For instance, on the Rio Puerco and at other points where the full section of the Nacimiento group is represented, the Torrejon formation is more than 500 feet stratigraphically above the base of the Puerco. From the Rio Puerco, where the full section of the group is present, the base of the Puerco formation was traced westward very definitely to the Arroyo Torrejon. In the latter district some of the upper members of the Puerco are notably absent and the Torrejon fossil mammals were secured at a little over 200 feet above the base of the Puerco, thus indicating an unconformity at that point unless a very notable thinning takes place in only the upper member of the Puerco. Since the members in the lower portion of the Puerco are persistent across the area and since the vertical distance between the base of the Puerco and the base of the Torrejon is scarcely sufficient to represent the great time-interval indicated by the evolution of the Torrejon fauna, it seems highly probable that the Torrejon is unconformable here. The stratigraphic section as prepared on the east fork of the Arroyo Torrejon is given below:

SECTION OF THE NACIMIENTO GROUP ON THE EAST FORK OF  
ARROYO TORREJON, FOUR MILES EAST OF THE  
FARMINGTON ROAD

		Thickness in Feet
(Wasatch, massive, conglomeratic sandstone at base)		
(Unconformity)		
Torrejon	Shale, drab and gray.....	14
	Shale, dark, carbonaceous and thin sandstone.....	20
	Sandstone, soft, gray and reddish shale.....	16
	Shale, black, yellow, drab, and gray .....	35
	Sandstone, soft, tan-colored.....	20
	Shale, gray, strongly arenaceous (fossil mammals).....	35
(Unconformity?)		
Thickness of formation		140
Puerco	Shale and soft sandstone.....	100
	Sandstone, massive, coarse-grained, tan-colored.....	30
	Shale, red, purple, drab, and white.....	30
	Shale, sandy, gray, dark, and yellowish.....	50
(Unconformity)		
Thickness of formation		210
"Laramie," sandstone, massive, brown		Thickness of group
		350

The third member above the base of the Puerco in the above section is a very persistent horizon-marker and corresponds to the fourth member above the base of the Puerco in the section previously given along the Puerco River; this member was traced continuously from the Nacimiento Mountains to beyond the Arroyo Torrejon.

The sedimentary record as preserved in the strata of the Nacimiento group is capable of slight variance of interpretation in respect



FIG. 7.—Shale of the Nacimiento group, three miles northeast of Nacimiento, New Mexico. Short distance west of the preceding view.

to origin. It is evident, however, that they were deposited in fresh water as shown by both the lithologic composition and the fossils. The beds may be largely the result of accumulation of sediment on the floor of an extensive fresh-water lake with alternate flooding and withdrawal of water, or they may have resulted chiefly from confluent alluvial fans along broad streams; or more probably the physiography involved a combination of the two conditions.

There is a notable absence of chemical deposits in the formations



under discussion except those resulting from secondary deposition or weathering. There are occasional concretions of barite observed by the writer in the Torrejon shale ten miles northeast of Encina Spring, which may be nearly contemporaneous with the rocks which inclose them. These are rough, irregular-shaped, often discoidal aggregations of impure barium sulphate; they lie imbedded in clay shale with which they harmonize closely in color, being usually dark gray with a slightly bluish tinge. It is quite possible that they represent the segregation of this slightly soluble salt at the time of deposition or while the shale was in a semiplastic state. Neither the Puerco nor Torrejon, so far as known, contains any primary deposits of salt, gypsum, or limestone; rarely there are present thin lenses of dark-colored limonite.

The beds of the Nacimiento group show evidences of the existence of currents from time to time during their deposition. Thin layers of small quartz pebbles and cross-bedding are not uncommon. The sudden termination along the bedding of massive sandstones is quite common and in the absence of faults can scarcely be accounted for except by the effects of stream-channels. The presence of smooth, globular forms of siliceous sandstone within sandstone of a similar matrix may be accounted for by either concretionary forces or by the action of currents. The variegated shale layers common to the upper beds and the overlying Wasatch formation probably represent varying degrees of oxidation at or near the surface during deposition.

It is the writer's opinion that the materials of the Nacimiento group in this region were transported by broad, shallow streams and laid down in deltas, lagoons, and shallow fresh-water lakes over a broad peneplaned surface. At the close of the Cretaceous, this portion of the continent was possibly slightly above sea-level, the elevation having been gradual from the time of marine deposition of the Lewis shale on through a time of brackish and fresh-water accumulation to land conditions at the close of the "Laramie." There was then a period of widespread orogenic movement, mountain growth, and attendant structure, accompanied and followed by erosion and accumulation of local, fresh-water sediments; at this time the formations of the Shoshone group, including the Arapahoe and Denver formations, of the Denver Basin, and the Animas formation of the

San Juan Basin were deposited. The uplift in the San Juan Mountains of southwestern Colorado at the close of the "Laramie" folded the Cretaceous sediments steeply along its flanks, but at some distance from them the sedimentary rocks were only slightly disturbed and possibly at no great elevation above tide. While local deposition was in process at this time in certain regions near the mountains, the elevated sedimentaries over other, perhaps extensive, areas were



FIG. 8.—Shale in the Wasatch formation, six miles southwest of Gallina, New Mexico, similar in appearance to the Nacimiento, but usually more highly variegated.

being reduced to base-level. By the beginning of Puerco time an extensive gently sloping plane had been produced over which broad streams flowed quietly to the sea, depositing sediment in shallow lakes and lagoons along their courses and at times shifting in position or overflowing and commingling with each other. Such a theory seems to explain the nature of the deposits as well as the conditions suitable to the fauna. In order to account for the thickness of the sediments deposited in this manner it seems necessary to assume that a slow submergence of the land kept equal pace with deposition.

The Nacimiento beds probably once extended far beyond the present confines of the Eocene in the San Juan Basin; possibly southward toward the Gulf of Mexico and westward into Arizona and Utah. The beds are confined to this basin at present because it owes its origin to structure which was produced certainly in part, and perhaps largely, after the close of Nacimiento time. Subsequent erosion has removed the formations of this group probably over extensive bordering regions while within the basin they are preserved by a thick covering of Wasatch. The Nacimiento Mountains, which limit the basin on the east, were surely elevated after the close of Nacimiento time, since the strata of that group are tilted at high angles and even overturned along its flanks. These mountains are of laccolithic origin and both the Puerco and Torrejon undoubtedly at one time continued beyond them.

#### FOSSILS

The fossils thus far found in the beds of the Nacimiento group by Baldwin and subsequent collectors are chiefly vertebrates and in a large measure representatives of the Mammalia. There are several genera and species among the Reptilia and fragments of bones of undetermined specimens of Aves. Of the Mollusca, four fresh-water forms from the Puerco, near the town of Nacimiento, were sent to Cope and described by Dr. C. A. White in 1886.<sup>23</sup> Among these forms, White doubtfully determined one species as *Unio rectoides* which he had found in the base of the Wasatch near Wales, Utah. Unfortunately the Nacimiento has furnished no fossil leaves, the only indications of flora being found in the form of silicified limbs, trunks, and stumps of dicotyledonous and palm trees.

The following remarks relative to the fossil mammals of the Nacimiento group are quoted from Professor H. F. Osborn:<sup>65</sup>

#### POLYMASTODON ZONE (PUERCO FORMATION)

Small archaic mammals evolving from Cretaceous, Jurassic, and Triassic ancestors. Multituberculata, which originated in the Triassic, 3 families. Two orders of archaic ungulates—(1) Amblyopoda-Periptychidae, (2) Condylarthra-Phenacodontidae. Archaic Carnivora-Creodonta, 3 families: (1) Oxyclaenidae, (2) Mesonychidae-Triisodontinae, (3) Arctocyoniidae (*Claenodon protogonoides*). Edentata-Taeniodonta, with enameled teeth, 2 families: (1) Stylinodontidae, (2) Conoryetidae.

## SUMMARY OF GENERA AND SPECIES

	Genera	Species
Archaic Triassic mammals .....	3	5
Archaic Cretaceous mammals.....	15	24
Total archaic mammals.....	18	29
Modernized or distinctively Tertiary mammals..	0	0

The Puerco is a fauna wholly of Mesozoic origin, and mostly destined to disappear; not a single representative or ancestor of any existing order of Tertiary mammals is certainly known. Cope's opinion that many of these mammals were ancestral to the modernized mammals lacks direct confirmation at present. Other paleontologists, however, are inclined to connect certain of the creodont families with the modern Carnivora. These and other ancestral connections may be demonstrated in the future.

Negatively, therefore, the Puerco is distinguished by the absence of primates, rodents, true carnivores, specialized insectivores, artiodactyls, perissodactyls, etc. This generalization has hardly less important bearings on paleogeography than on paleozoölogy.

## PANTOLAMBDA ZONE (TORREJON FORMATION)

Like the Puerco this is almost exclusively a Mesozoic fauna, destined to become extinct during the Eocene. The known exceptions in surviving types are the pro-Carnivora-Miacidae, which first appear at this stage. Others will be discovered.

Mammals of larger size, mostly evolved from the Puerco mammals. Last survivors of the Multituberculata. Edentata-Taeniodonta of larger size. Of archaic Ungulata, 2 orders and 3 families: (1) Condylarthra-Phenacodontidae, (2) Amblypoda-Periptychidae, (3) Amblypoda-Pantolambdidae. Of the latter, *Pantolambda* is supposed to be ancestral to the Coryphodontidae of the Wasatch. Carnivora-Creodonta, 4 families: (1) Mesonychidae, (4) pro-Carnivora-Miacidae. The primate-like *Indrodon* and aberrant *Mixodectes* are of unknown relationships; they are possibly Insectivora.

## SUMMARY OF GENERA AND SPECIES

	Genera	Species
Archaic Triassic stock.....	3	4
Archaic Cretaceous stock.....	21	36
Total archaic stock .....	24	40
Modernized Tertiary stock.....	1	1

## LIST OF FOSSILS FOUND IN THE PUERCO AND TORREJON FORMATIONS

## MAMMALIA\*

Puerco	Torrejon
Polymastodon zone	Pantolambda zone
1. San Juan Basin, New Mexico	1. San Juan Basin, New Mexico
	2. Fort Union formation (in part), Montana

## MULTITUBERCULATA

*Plagiaulacidae*

	1		1	2
<i>Neoplagiaulax americanus</i> Cope...	×	<i>Neoplagiaulax molestus</i> Cope...	×	
<i>Catopsalis joliatus</i> Cope.....	×	<i>Ptilodus mediaevus</i> Cope.....	×	
<i>Polymastodon taoensis</i> Cope.....	×	<i>Ptilodus trovessartianus</i> Cope...	×	
<i>Polymastodon attenuatus</i> Cope.....	×	<i>Ptilodus plicatus</i> Cope.....	×	
<i>Polymastodon selenodus</i> O. and E..	×	<i>Ptilodus montanus</i> Douglass....		×
		<i>Ptilodus gracilis</i> Gidley.....		×
		<i>Polymastodon fissidens</i> Cope...		?

## CREODONTA

*Miacidae*

*Didymictis haydenianus* Cope... ×

*Arctocyoniidae*

(?)

*Claenodon corrugatus* (Cope)... ×

*Claenodon jerox* (Cope)..... ×

?*Claenodon protogonioides*

(Cope)..... ×

*Mesonychidae*

*Dissacus navajovius* Cope..... ×

*Dissacus saurognathus* Wortman ×

*Triisodontidae*

*Triisodon quivirensis* Cope ..... × *Sarcothraustes antiquus* Cope... ×

*Triisodon heilprinianus* Cope..... × *Goniacodon levisanus* Cope... ×

*Triisodon gadrianus* Cope..... × *Microclenodon assurgens* Cope.. ×

*Oxyclaenidae*

*Oxyclaenus cuspidatus* Cope..... × *Chriacus pelvidens* (Cope)..... ×

*Oxyclaenus simplex* (Cope)..... × *Chriacus baldwini* Cope..... ×

*Loxolophus hyattianus* (Cope)..... × *Chriacus truncatus* Cope..... ×

*Loxolophus priscus* (Cope)..... × *Chriacus schlosserianus* Cope... ×

*Loxolophus attenuatus* O. and E.. × *Tricentes subtrigonus* (Cope)... ×

*Carcinodon filholianus* (Cope)..... × *Tricentes crassicollidens* Cope... ×

*Paradoxodon rutimeyeranus* (Cope) × *Deltatherium fundamini* Cope. ×

\* The arrangement of the list of mammals is that of Dr. W. D. Matthew. See bibliography, No. 65.

## INSECTIVORA

*?Hyopsodontidae*

<i>Mioclænus turgidunculus</i> Cope....	×	<i>Mioclænus turgidus</i> Cope.....	×
		<i>Mioclænus lemuroides</i> Matthew	×
		<i>Mioclænus acolytus</i> Cope.....	×
		<i>Mioclænus lydekkerianus</i> Cope.	×
		<i>Mioclænus inaequidens</i> (Cope).	×
		<i>?Protoselene opisthacus</i> (Cope).	×

*Incertae sedis*

<i>Oxyacodon apiculatus</i> O. and E....	×
<i>Oxyacodon agapetillus</i> (Cope).....	×

*Pantolestidae*

<i>Pentacodon inversus</i> Cope.....	×
--------------------------------------	---

*Mixodectidae*

<i>Mixodectes pungens</i> Cope.....	×
<i>Mixodectes crassiusculus</i> (Cope)	×
<i>Indrodon malaris</i> Cope.....	×

## TAENIODONTA

*Stylinodontidae*

<i>Wortmania otariidens</i> Cope.....	×	<i>Psittacotherium multijragum</i>	
		Cope.....	×

*Conoryctidae*

<i>Onychodectes tisonensis</i> Cope.....	×	<i>Conoryctes comma</i> Cope.....	×
<i>Onychodectes rarus</i> O. and E.....	×		

## CONDYLARTHRA

*Phenacodontidae*

<i>?Protonodon pentacus</i> Cope.....	×	<i>Tetraclaenodon puercensis</i>	
<i>?Protonodon stenognathus</i>		(Cope).....	×
Matthew.....	×	<i>Tetraclaenodon minor</i> (Matthew)	×

## AMBLYPODA

*Periptychidae*

<i>Periptychus coarctatus</i> Cope.....	×	<i>Periptychus carinidens</i> Cope...	×
<i>Ectoconus ditrigonus</i> (Cope).....	×	<i>Periptychus rhabdodon</i> (Cope)..	×
<i>Conacodon entoconus</i> (Cope).....	×	<i>Haploconus lineatus</i> Cope.....	×
<i>Conacodon cophater</i> (Cope).....	×	<i>Haploconus corniculatus</i> Cope..	×
<i>Anisonchus gillmanus</i> Cope.....	×	<i>Anisonchus sectorius</i> Cope.....	×
<i>Hemithlaeus kowalevskianus</i> Cope..	×		

*Pantolambdidae*

<i>Pantolambda bathmodon</i> Cope..	×
<i>Pantolambda caviroctus</i> Cope...	×

The following fossils other than mammalia have been found in beds of the Nacimiento group in New Mexico:

## REPTILIA

## CROCODILIA

Several new undescribed species

## TESTUDINATA

*Conchochelys admirabilis* Hay (Nacimiento)

*Plastomenus acupictus* Hay (Torrejon)

*Aspideretes singularis* Hay (Torrejon)

*Platypeltis antiqua* Hay (Torrejon)

*Plastomenus? communis* Cope

*Chelydra crassa* Cope

*Dermatemys* sp.

*Compsemys* sp.

*Emys* sp.

## RHYNCOCEPHALIA

*Champsosaurus australis* Cope

*Champsosaurus puericensis* Cope

*Champsosaurus saponensis* Cope

## OPHIDIA

*Helagras prisciformis* Cope

## AVES

Fragments of bones of undetermined species

## MOLLUSCA

*Helix nacimientensis*

*Helix adipis*

*Pupa leidy* (?)

*Unio rectoides* (?)

## FLORA

Wood of dicotyledonous and palm trees, undetermined

The fossil mammal teeth shown in Fig. 9 were collected by the writer in 1907 from the Torrejon formation eight miles northeast of Encina Spring, New Mexico (see Plate I). These fossils are in the hands of Mr. James W. Gidley, custodian of fossil mammals in the National Museum. He furnishes the following identifications of them which are subject to correction. There are new genera and species represented which will be described fully in a forthcoming paper by Mr. Gidley.

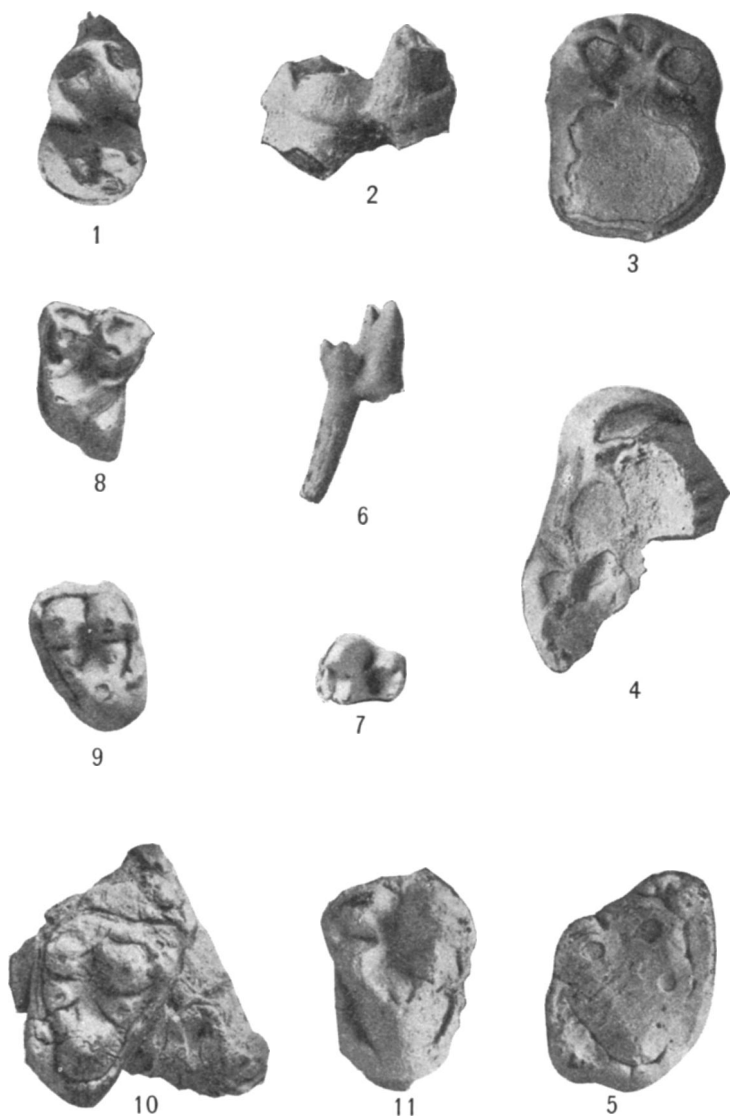


FIG. 9.—Fossil mammal teeth from the Torrejon formation, magnified 3 diameters, except No. 9, which is 4 diameters.



No. 1. *Chriacus plevidens* (Cope), last right lower molar, crown view. Accession No. 5713.

No. 2. Same as No. 1 (side view).

No. 3. *Periptychus carnidens*, left lower molar,  $m_2$ , crown view. Accession No. 5707.

No. 4. *Periptychus carnidens*, right lower premolar, ?  $p_3$ , crown view. Same individual as No. 3.

No. 5. *Euprotogonia puercensis*, last right upper molar, crown view. Accession No. 5710.

No. 6. *Insectivor*, new genus and species, right lower molar, ?  $m_2$ , side view. Accession No. 5715.

No. 7. Same as No. 6, crown view.

No. 8. *Olbodotes* ? *copei*, second upper molar of left side, crown view. Accession No. 5714.

No. 9. *Oxyclaenus* sp., second upper molar of left side crown view. Four times natural size.

No. 10. *Tricentes subtrigonus*, second upper molar of right side in fragment of jaw, crown view. Accession No. 5709.

No. 11. *Miacidae*, genus and species new, second upper molar of right side, crown view. Accession No. 5712.

#### CORRELATIONS

With the exception of a small area in Montana where Torrejon fossils have been found, neither of the faunas of the Nacimiento group is known in North America outside of the one limited region in the San Juan Basin of northwestern New Mexico.

The beds in Montana which contain the Torrejon fossils were discovered by Mr. Earl Douglass in 1901.<sup>52</sup> The first fossils were found near Fish Creek in Sweetgrass County, T. 6 N., R. 16 E., in beds of Fort Union age. A collection of leaves from a sandstone overlying the shale containing Torrejon vertebrates was sent to Dr. F. H. Knowlton who pronounced the species all Fort Union beyond a doubt. In 1908 and 1909 collections for the U.S. National Museum were made in this region by Messrs. A. C. Silberling and J. W. Gidley. All who have worked in the district agree that the fossils are in the Fort Union and all who have studied the fauna, including Scott, Matthew, Gidley, Farr, and Douglass, agree that the fossils are Torrejon. In that region beneath the Fort Union, containing the fossil mammals, is the Lance formation or "Ceratops beds." This formation contains dinosaurs and is Cretaceous in age, unless perchance dinosaurs lived into Tertiary time as the flora seems to

indicate. The evidence as to the age of these beds is conflicting when viewed from different paleontological standpoints, and has led to an interesting discussion by Stanton<sup>69</sup> and Knowlton.<sup>68</sup> But so far no fossils of the lower formation of the Nacimiento group, or Puerco, have been found in Montana. It is quite possible that they may be discovered later either in lower beds of the Fort Union or in the underlying Lance formation.

There is one locality on the south side of the San Juan Basin, namely at Ojo Alamo (see Plate II), where the writer obtained dinosaurs from beds unconformably above the "Laramie" and below the Wasatch. Mr. C. W. Gilmore of the U.S. National Museum reports that they appear to represent a typical fauna of the "Ceratops beds." The beds at Ojo Alamo have been searched in vain for fossil mammals and have furnished several new species of fossil turtles, but the fact remains that so far they have not been correlated with any other formation of that basin. They are very similar in appearance to the beds of the Nacimiento group, are only a short distance west of the Puerco region, and occupy the interval between the "Laramie" and Wasatch. Their definite relation to the Nacimiento group must be left for future elucidation.

There are two foreign countries where faunas closely related to those of the Nacimiento group have been found, one in Europe, the other in South America.

The Thanetien, or Cernaysien, of France, corresponds broadly with the Puerco and Torrejon.<sup>32, 48, 65</sup> As pointed out by Osborn,<sup>65</sup> the fauna of the "Conglomerat de Cernay" near Rheims shows a homotaxis with that of the Torrejon by similar stages of evolution in the representatives of three families, namely, (1) Plagiaulacidae, (2) Arctocyoniidae, and (3) Mesonychidae-Triisodontidae. Other identifications are very uncertain.<sup>32</sup> Professor Charles Depéret, of the University of Lyons, correlates the beds of Cernay with those near La Fère, Rilly, Châlons-sur-Vesle, in France, and the Erguelines in Belgium.

In South America, the basal Eocene or Notostylops beds of Patagonia contain fossil mammals similar to those of the Puerco formation,<sup>65</sup> thus probably indicating a contemporary or previous land connection between the two Americas.

## SUMMARY

The beds comprising the Nacimiento group were discovered by Professor E. D. Cope<sup>5</sup> in 1874 on the head drainage of the Puerco River in the San Juan Basin, northwest New Mexico. In 1875, these beds were thought to have been identified on the opposite side of the basin in New Mexico by Dr. W. H. Holmes.<sup>8</sup> The same year Dr. F. M. Endlich<sup>7</sup> working in the San Juan Basin north of the New Mexico boundary line correlated with the Puerco a series of beds along the Animas River in southwest Colorado. These correlations of the Puerco by Holmes and Endlich were based entirely on lithologic resemblance and stratigraphic position. The beds spoken of by Holmes<sup>8</sup> in his Pinyon Mesa section may be either Puerco or younger, while the beds described by Endlich<sup>7</sup> and shown on Hayden's Preliminary Map of Central Colorado are now known by the writer to be identical in larger part with the Animas formation of Dr. Whitman Cross.<sup>34</sup>

The name Torrejon was proposed by Dr. J. L. Wortman in 1897<sup>42</sup> for those beds previously known as the upper part of the Puerco, but which contain species of fossil vertebrates totally different from those of the lower beds, subsequently known as Puerco proper. The discovery of the Torrejon fauna was due to Dr. Wortman's observations in the field in 1892<sup>37</sup> together with paleontologic records kept by the American Museum of Natural History.

The Puerco and Torrejon formations have not been identified over wide areas. All the fossils collected from these formations came from limited districts in northwest New Mexico until recent years. Neither of the two formations had been positively identified beyond this region, nor similar fossils found elsewhere, until 1901. That year Mr. Earl Douglass<sup>52</sup> discovered Torrejon vertebrates near Fish Creek of the Musselshell River, Montana. The U.S. National Museum has since made extensive collections of these fossils, but no typical Puerco fauna has yet been discovered in North America outside of the San Juan Basin in northwest New Mexico. As has already been set forth, the "Laramie" and the Nacimiento of the San Juan Basin were each followed by a stratigraphic break, involving a considerable erosion-interval and marked faunal change. An unconformity of less importance separates the two formations of

the Nacimiento group. Unfortunately, no flora has been discovered from either of these formations. The great break in the character of the fossil vertebrates in passing from one formation to the other, or to the underlying "Laramie" and overlying Wasatch, has long been a puzzle. The beds were thought by Cope to lie conformably on the "Laramie" and in turn to be overlain conformably by the Wasatch. This idea was borne out by later authors on the subject and collectors in the field. Not until the work of the writer in 1907, however, had there been any attempt at mapping the formations. It was in connection with tracing the formation boundaries and a study of the physiographic record that the unconformities became evident. Lithologically the Torrejon is not sufficiently distinct from the Puerco to permit of its being readily mapped in the field, the separation being made on fossil evidence.

In this paper the topography, structure, stratigraphy, and physiographic record of the Puerco district have been described for the first time with the exception of a brief reference by the writer in one of the bulletins of the U.S. Geological Survey.<sup>70</sup>

The faunas of the Nacimiento group are unique. The upper fauna, the Torrejon, is known in only one limited area of North America outside of the type-locality. This is east of the Crazy Mountains in Montana. The lower fauna, the Puerco, is not known to occur in America except in the San Juan Basin of New Mexico. Outside of North America, fossils closely related to those of the Nacimiento group have been found in certain districts of Europe and South America, the European localities being confined to France and Belgium, where fossil mammals are known in the early Eocene corresponding closely to those of the Torrejon formation, while fossil mammals more nearly related to those of the Puerco formation are found in Patagonia.

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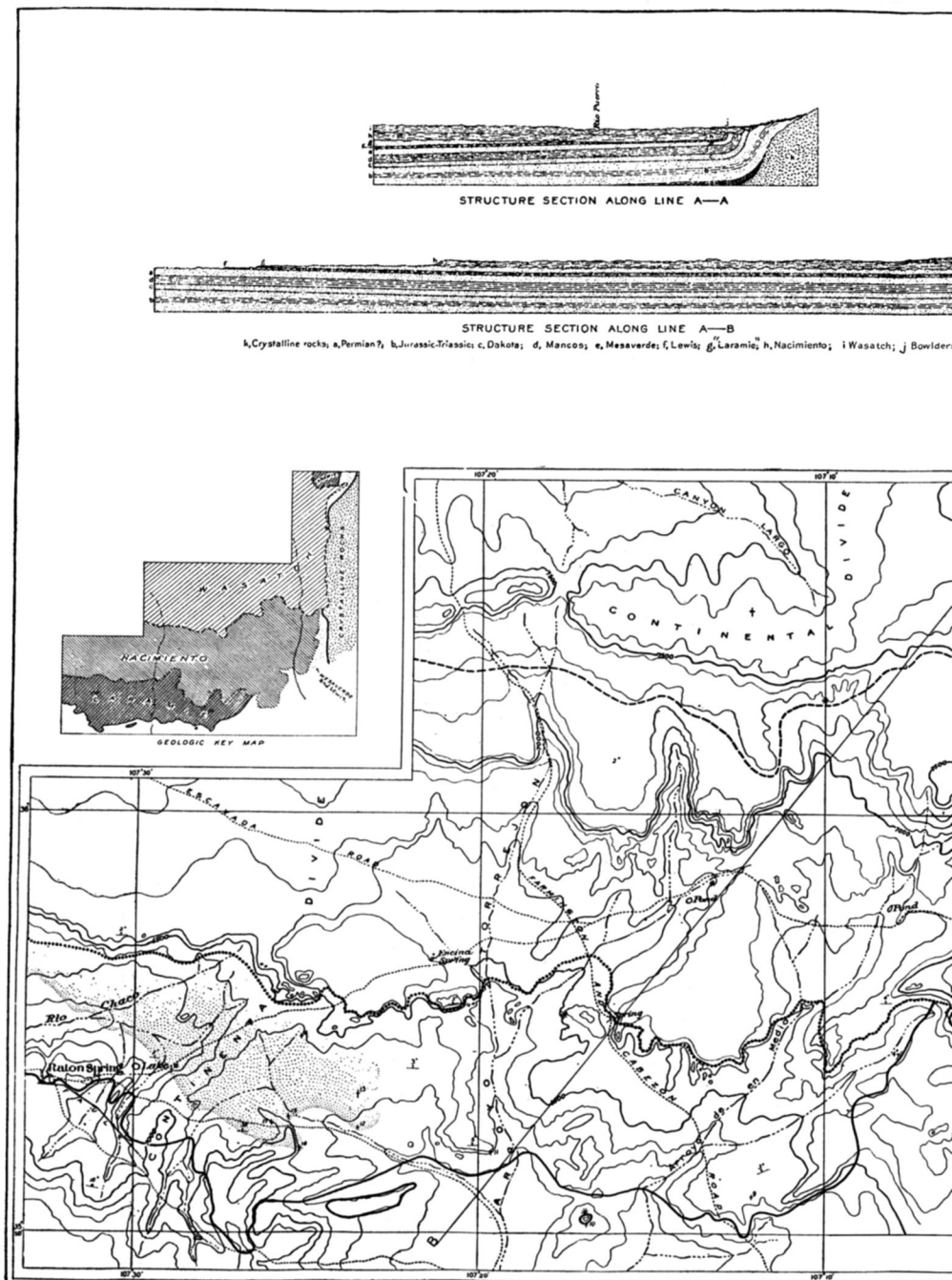
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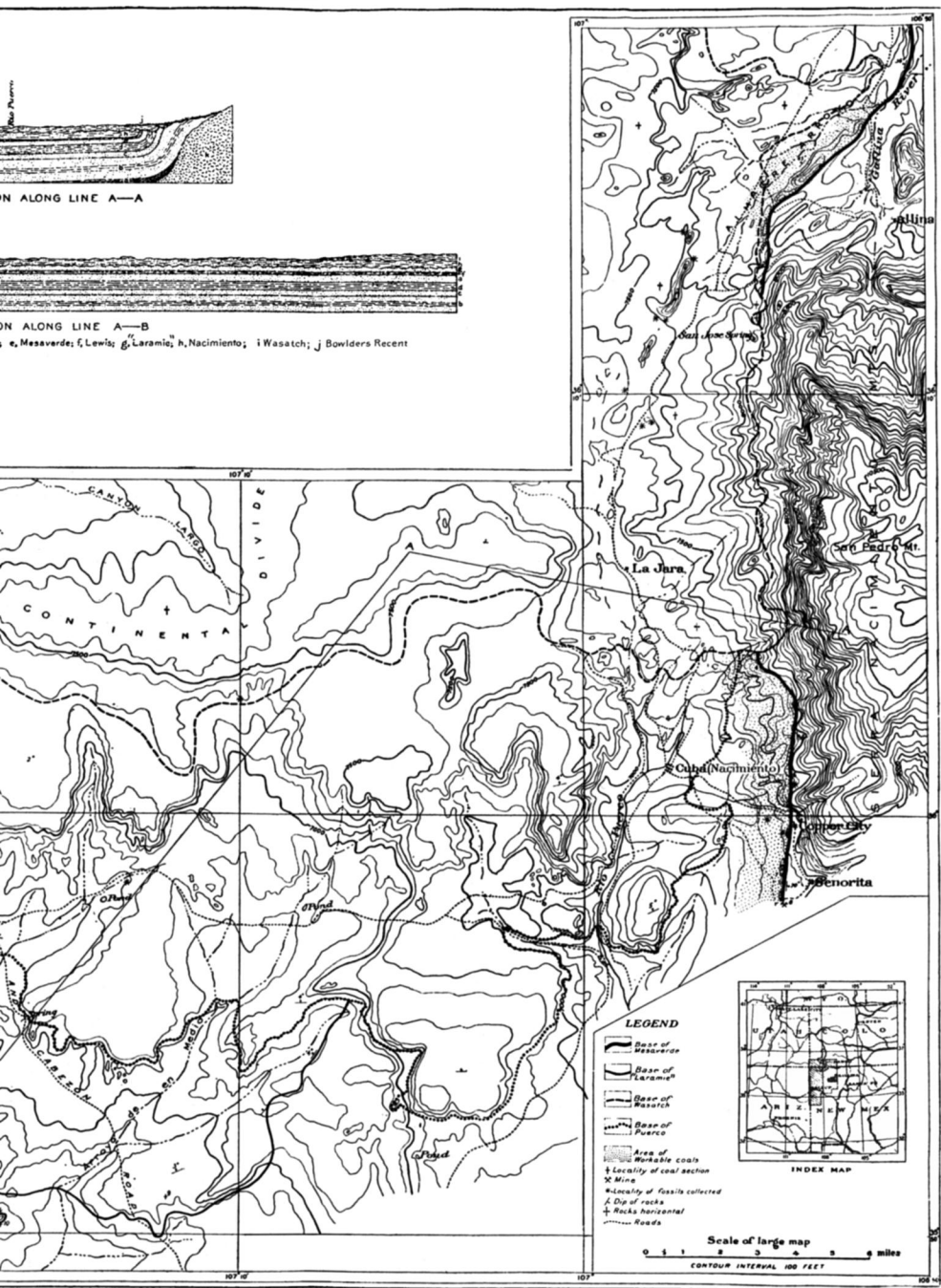
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MAP OF THE PUERCO AND TORREJÓN TYPE  
 NEW MEXICO.



TORREY AND TORREJON TYPE LOCALITY  
NEW MEXICO.